1. PUBLIC HEALTH STATEMENT

This public health statement tells you about selenium and the effects of exposure.

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sites make up the National Priorities List (NPL) and are the sites targeted for long-term federal cleanup activities. Selenium has been found in at least 494 of the 1,585 current or former NPL sites. However, the total number of NPL sites evaluated for this substance is not known. As more sites are evaluated, the sites at which selenium is found may increase. This information is important because exposure to this substance may harm you and because these sites may be sources of exposure.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You are exposed to a substance only when you come in contact with it. You may be exposed by breathing, eating, or drinking the substance, or by skin contact.

If you are exposed to selenium, many factors determine whether you'll be harmed. These factors include the dose (how much), the duration (how long), and how you come in contact with it. You must also consider the other chemicals you're exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

1.1 WHAT IS SELENIUM?

Selenium is a naturally occurring, solid substance. It is widely but unevenly distributed in the earth's crust. It is commonly found in rocks and soil. Selenium, in its pure form of metallic gray to black hexagonal crystals, is often referred to as elemental selenium or selenium dust. However, in the environment, selenium is not often found in this pure form. It is usually combined with other substances. Much of the selenium in rocks is combined with sulfide minerals or with silver, copper, lead, and nickel minerals.

In the environment, selenium combines with oxygen to form several substances. The most common are sodium selenite and sodium selenate. Pure sodium selenite and selenate are white or colorless crystals. Selenium sulfide is an insoluble, bright red-yellow powder that is used in anti-dandruff shampoos. When used in anti-dandruff shampoos, it is known by the common trade name Selsun Blue. Some selenium compounds are gases. Hydrogen selenide (also called selenium hydride) is a colorless gas with a disagreeable odor. Although other selenium forms may be in dust in the air, hydrogen selenide is probably the only gaseous selenium compound that might pose a health concern in occupational settings. Selenium dioxide is an industrially

produced compound that easily dissolves in water to form selenious acid. Selenious acid can be found in gun blueing (a liquid solution used to clean the metal parts of a gun). Levels at which you begin to smell or taste selenium compounds in air or water are not available. The only exception is for selenium dioxide. It has a sharp, sour odor that you can smell when its concentration in the air goes above about 200 nanograms per cubic meter (ng/m^3; a nanogram is $1/1,000,000,000^{th}$ of a gram).

Plants easily take up selenium compounds from water and change them to organic selenium compounds such as selenomethionine (a transparent solid in pure form). Selenium is an essential nutrient for humans and animals, and both can use inorganic as well as organic selenium compounds. The human recommended dietary allowance (RDA) of selenium for maintenance of good health is 55 µg/day (a µg is $1/1,000,000^{th}$ of a gram) for adults. Although it is an essential nutrient, selenium can harm people and animals when consistently eaten in amounts higher than those needed for good nutrition.

Burning coal—especially the fly ash that comes from burning coal—is the major man-made source of selenium in the environment. Elemental selenium is also commercially produced, primarily as a by-product of copper refining. In 1996, U.S. production of selenium was 379 metric tons. Examples of uses for selenium and its compounds are some photographic devices (because of its semiconductor and photoelectric properties), plastics, paints, anti-dandruff shampoos, vitamin and mineral supplements, fungicides, and certain types of glass. Selenium is also used to prepare drugs and as a nutritional feed for poultry and livestock. For instance, in some European countries, sodium selenate is found in drenches (large doses of liquid medicine) used to supplement the diets of cattle and sheep grazing on selenium-deficient soils. When selenium is found in vitamin and mineral supplements, it is usually listed on the content label as "selenium."

Selenium can exist at hazardous waste sites in many forms. However, specific forms have not been analyzed at sites where selenium is reported. At hazardous waste sites, you could be exposed to selenium by swallowing the soil or water, or by breathing the dust. Eating plant products that have taken up selenium from soil and water in areas of high concentration could also result in indirect exposure at regulated waste sites. The form selenium takes at any given time depends on the environmental conditions. This is further discussed in Chapter 6.

Chapter 4 has more information on the physical and chemical properties of selenium and its compounds. Chapter 5 provides more information on the sources and uses of selenium.

1.2 WHAT HAPPENS TO SELENIUM WHEN IT ENTERS THE ENVIRONMENT?

Although selenium occurs naturally in the environment, it also can be released by both natural and manufacturing processes. As an element (its simplest form), selenium cannot be created or destroyed. However, selenium can change forms in the environment. Weathering of rocks to soil may cause low levels of selenium in water or may cause selenium to be taken up by plants or released on fine dust-like particles into the air. Volcanic eruptions are suspected of contributing to selenium in air, and soils in the areas around volcanos contain more selenium.

More commonly, selenium enters the air from burning coal or oil. Much of the selenium in air is attached to fly ash and to suspended particles. The elemental selenium that may be present in fossil fuels forms selenium dioxide when burned. Selenium dioxide can then form selenious acid with water or sweat. Selenium anhydride is released during the heating of copper, lead, and zinc ores when there is selenium in them. Hydrogen selenide breaks up rapidly in air to form elemental selenium and water, thus eliminating the danger from this compound for most people, except those who are exposed to it in their workplace.

Airborne particles of selenium, such as in ash, can settle on soil or surface water Disposal of selenium in commercial products and waste could also contribute to selenium levels in soil. However, the amount of selenium released to soil from ash and hazardous waste sites has not been measured. The forms and fate of selenium in soil depend largely on the acidity of the surroundings and its interaction with oxygen. In theory, with no oxygen present, deep soil selenium may be present as elemental selenium. In the absence of oxygen when the soil is acidic, the amount of biologically available selenium should be low. Elemental selenium that cannot dissolve in water and other insoluble forms of selenium (such as selenium sulfide and heavy metal selenides) are less mobile and will usually remain in the soil, posing less of a risk for exposure. Active agricultural or industrial processes may increase the amount of biologically available selenium by decreasing the acidity of the soil and increasing the oxygen and the soluble selenium compounds. Selenium compounds that can dissolve in water are very mobile. For example, selenates and selenites are water soluble, and thus mobile, so there is an increased chance of exposure to them. Selenium may enter surface water in irrigation drainage waters. Factors that may affect how fast selenium moves through soil are temperature, moisture, season of year, concentration of water-soluble selenium, organic matter content, and microbiological activity.

Some evidence indicates that selenium can be taken up in tissues of organisms and possibly increase in concentration in aquatic organisms as the selenium is passed up through the food chain. Selenium concentrations in organisms living in water have been a problem as a result of irrigation runoff in some dry areas of the United States. It is important to remember that

selenium's behavior in the environment is largely affected by the surrounding conditions and by how it interacts with other compounds. Chapter 6 contains more information on what happens to selenium in the environment.

1.3 HOW MIGHT I BE EXPOSED TO SELENIUM?

People can be exposed to selenium in several ways and environments. They could be exposed to higher-than-normal levels of selenium at hazardous waste sites. Exposure may occur through locally grown food, water, soil, and/or air that contains selenium particularly at higher-than-normal levels. Research shows that the most significant exposure to selenium comes from eating food, and to a lesser extent, from water intake. For example, in certain areas of China, villagers used coal ash high in selenium to fertilize their crops. After many years, the vegetables from these areas, their main source of food, had large amounts of selenium. Selenium can also be washed from the soil at hazardous waste disposal sites into surface water or can flow into groundwater. Occasionally, water containing selenium may seep from abandoned uranium or coal mining areas into groundwater, or into rivers or streams. This can eventually enter into drinking water systems.

People may also be exposed to selenium from industrial sources. Humans are normally not exposed to large amounts of selenium in the air, unless selenium dust or volatile selenium compounds are formed in their workplace. Occupations in which humans may be exposed to selenium in the air are the metal industries, selenium-recovery processes, paint manufacturing, and special trades. Selenium dioxide and elemental selenium can be released into the air during the burning of coal and oil. In addition, irrigation runoff may cause high levels of selenium in fresh water and can lead to high concentrations in some of the fish and birds that live there.

Because selenium is naturally occurring and widespread, people are also exposed to low levels of selenium daily through food, water, and air. Estimates of the average intake of selenium from food for the U.S. population range from 71 to 152 micrograms of selenium per person per day (µg selenium/day). Generally, the levels in food in the United States are enough to protect against diseases that may result from too little selenium. Most of the daily intake of selenium comes from eating grains, cereals, and meat. Selenium in food is primarily in the form of selenoamino acids (organic selenium compounds). In some parts of the United States, especially in the western states, the soils naturally have high levels of selenium compounds. Some plants can build up selenium to levels that harm livestock feeding on them. In these areas, people could be exposed to too much selenium if they eat a lot of locally grown grains and vegetables that have built up high levels of selenium. However, tests of people in areas of the western United States with high soil selenium levels show none of the negative health effects associated with

selenium that were seen in Chinese villagers who had eaten much larger amounts of selenium for longer periods.

Low levels of selenium can also be found in drinking water. Most of the water sources tested in the United States have very low levels of selenium compared with the levels found in food. Selenium levels were less than 10 ppb (10 parts of selenium in a billion parts of water) in 99.5% of drinking water sources tested. The 10-ppb concentration is lower than the 50-ppb Maximum Contaminant Level (MCL), which the EPA believes will protect against adverse health effects. Less than 1% of the daily intake of selenium is estimated to come from drinking water.

Chapter 6 contains more information on how people can be exposed to selenium.

1.4 HOW CAN SELENIUM ENTER AND LEAVE MY BODY?

Selenium from the environment mainly enters the body when people eat food containing selenium. The human body easily absorbs the organic selenium compounds (for example, selenoamino acids) when eaten and makes them available where needed in the body. The selenium in drinking water is usually in the form of inorganic sodium selenate and sodium selenite; these are also easily absorbed from the digestive tract. The human body can change these inorganic selenium compounds into forms it can use. Selenium in the air may also enter your body when you breathe it.

Hazardous waste sites at which selenium is present could present a major source of exposure to selenium. The way that it can enter the body from a particular site depends on such things as whether vegetables are grown on soil in which selenium from the site has been deposited, whether water at the site contains selenium and is able to flow into drinking water supplies, and whether selenium dust blows into the air. As mentioned earlier, specific conditions at a site can greatly influence which selenium compounds form and whether they can move in the environment to places where people may be exposed. Therefore, it is important to know that the presence of selenium at a site does not necessarily mean that people are being exposed to it. Specific tests of locally grown food, drinking water, and air must be done to find out whether exposure is occurring. You should also be aware that selenium compounds, including those used in some medicated dandruff shampoos, are not easily absorbed through the skin.

Most of the selenium that enters the body quickly leaves the body, usually within 24 hours. Beyond what the body needs, selenium leaves mainly in the urine, but also in feces and breath. Selenium in the urine increases as the amount of the exposure goes up. Selenium can build up in the human body, however, if exposure levels are very high or if exposure occurs over a long time. It builds up mostly in the liver and kidneys but also in the blood, lungs, heart, and testes.

Selenium can build up in the nails and in hair, depending on time and amount of exposure. Chapter 3 contains more information on how selenium enters and leaves the human body.

1.5 HOW CAN SELENIUM AFFECT MY HEALTH?

To protect the public from the harmful effects of toxic chemicals and to find ways to treat people who have been harmed, scientists use many tests.

One way to see if a chemical will hurt people is to learn how the chemical is absorbed, used, and released by the body; for some chemicals, animal testing may be necessary. Animal testing may also be used to identify health effects such as cancer or birth defects. Without laboratory animals, scientists would lose a basic method to get information needed to make wise decisions to protect public health. Scientists have the responsibility to treat research animals with care and compassion. Laws today protect the welfare of research animals, and scientists must comply with strict animal care guidelines.

The general public rarely breathes high levels of selenium, although some people may be exposed to selenium dust and selenium compounds in workplace air. Dizziness, fatigue, and irritation of mucous membranes have been reported in people exposed to selenium in workplace air at concentrations higher than legal levels. In extreme cases, collection of fluid in the lungs (pulmonary edema) and severe bronchitis have been reported. The exact exposure levels at which these effects may occur are not known, but they become more likely with increasing amounts of selenium and with increasing frequency of exposure.

The normal intake of selenium by eating food is enough to meet the RDA of 55 μg/day for adults for this essential nutrient. However, as discussed in Chapter 2 of this profile, selenium compounds can be harmful at daily dietary levels that are higher than needed. The seriousness of the effects of excess selenium depends on how much selenium is eaten and how often. Intentional or accidental swallowing of a large amount of sodium selenate or sodium selenite (for example, a very large quantity of selenium supplement pills) could be life-threatening without immediate medical treatment. Even if mildly excessive amounts of selenium are eaten over long periods, brittle hair and deformed nails can develop. In extreme cases, people may lose feeling and control in arms and legs. These health effects, called selenosis, were seen in several villages in China where people were exposed to foods high in selenium for months to years. No human populations in the United States have been reported with long-term selenium poisoning, including populations in the western part of the country where selenium levels are naturally high in the soil. Because most people in the United States eat foods produced in many different areas, overexposure to selenium in food is unlikely to occur.

In some regions of China where soil levels of selenium are very low, not eating enough selenium has resulted in health effects. Selenium is used by the body in enzymes that protect against damage to tissues done by oxygen, and in an enzyme that affects growth and metabolism. Not eating enough selenium can cause heart problems and muscle pain. Muscle pain has also been noted in people fed intravenously for a long time with solutions that did not contain selenium. Babies born early may be more sensitive to not having enough selenium, and this may contribute to lung effects. In the United States, selenium in food is sufficient to meet the RDA and prevent harmful effects from not enough selenium.

Upon contact with human skin, selenium compounds have been reported to cause rashes, redness, heat, swelling, and pain. Brief, acute exposure of the eyes to selenium dioxide as a dust or fume in workplace air may result in burning, irritation, and tearing. However, only people who work in industries that process or use selenium or selenium compounds are likely to come into contact with levels high enough to cause eye irritation.

Studies of laboratory animals and people show that most selenium compounds probably do not cause cancer. In fact, studies of cancer in humans suggest that lower-than-normal selenium levels in the diet might increase the risk of cancer. But levels of selenium in the diet that are much higher than normal have not been shown to reduce the risk of cancer in humans. Taking selenium so that your daily amount is greater than that required may just increase your risk of selenium poisoning.

Based on studies up until 1987, the International Agency for Research on Cancer (IARC) determined that selenium and selenium compounds could not be classified as to their ability to cause cancer in humans. However, since then the EPA has determined that one specific form of selenium, called selenium sulfide, is a probable human carcinogen. Selenium sulfide is the only selenium compound shown to cause cancer in animals. Rats and mice that were fed selenium sulfide daily at very high levels developed cancer. Selenium sulfide is not present in foods, and it is a very different chemical from the organic and inorganic selenium compounds found in foods and in the environment. Also, if introduced into the environment, selenium sulfide does not dissolve readily in water and would probably bind tightly to the soil, further reducing any chance of exposure. Because selenium sulfide is not absorbed through the skin, the use of anti-dandruff shampoos containing selenium sulfide is generally considered safe.

Very high amounts of selenium have resulted in decreased sperm counts, increased abnormal sperm, changes in the female reproductive cycle in rats, and changes in the menstrual cycle in monkeys. The relevance of the reproductive effects of selenium exposure in animals studied to potential reproductive effects in humans is not known. Selenium compounds have not been shown to cause birth defects in humans or in other mammals.

Chapter 3 contains more information on the health effects of selenium and selenium compounds in humans and animals.

1.6 HOW CAN SELENIUM AFFECT CHILDREN?

This section discusses potential health effects from exposures during the period from conception to maturity at 18 years of age in humans.

Children living near selenium waste sites or coal burning plants are likely to be exposed to higher environmental levels of selenium through breathing, touching soil, and eating contaminated soil. Children living in areas of China with high selenium in the soil had higher levels of selenium in the blood than adults from that area. Very few studies have looked at how selenium can affect the health of children. Children need small amounts of selenium for normal growth and development. Children will probably show the same sort of health effects from selenium exposure as adults, but they may be less susceptible to health effects of selenium than adults.

We do not know if exposure to selenium will result in birth defects in people. Selenium compounds have not been shown to cause birth defects in humans or in other mammals. We have no information to suggest that there are any differences between children and adults in where selenium is found in the body or in how fast it enters or leaves the body. Studies in laboratory animals have shown that selenium crosses the placenta and enters the fetus. Studies in humans show that infants are supplied with selenium through breast milk, and therefore, women who were exposed to selenium by living near a waste site might transfer selenium to their babies. However, babies in areas of China with high selenium in the soil did not show any signs of health effects due to selenium, even though some of their parents did.

1.7 HOW CAN FAMILIES REDUCE THE RISK OF EXPOSURE TO SELENIUM?

If your doctor finds that you have been exposed to significant amounts of selenium, ask whether your children might also be exposed. Your doctor might need to ask your state health department to investigate.

Since selenium occurs naturally in the environment, we cannot avoid exposure to it. Certain dietary supplements and shampoos contain selenium. You should not exceed the recommended dosages when using these products.

Children living near selenium waste sites or coal burning plants are likely to be exposed to higher environmental levels of selenium through breathing, touching soil, and eating

contaminated soil. Some children eat a lot of dirt. You should discourage your children from eating dirt. Make sure they wash their hands frequently and before eating. Discourage your children from putting their hands in their mouths or from other hand-to-mouth activity.

The primary route of human exposure to selenium is through eating food. People who irrigate their home gardens with groundwater containing high levels of selenium may grow and eat plants that contain high levels of selenium because this element accumulates in some plants. Fishermen and hunters of waterfowl who regularly eat fish and game from waterways with high selenium content may also swallow above average levels of selenium. To reduce your family's exposure to selenium, obey any wildlife advisories issued by your state. Information on fish and wildlife advisories in your state is available from your state public health or natural resources department.

1.8 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO SELENIUM?

Selenium can be measured in the blood, urine, and fingernails or toenails of exposed individuals. However, since selenium is an essential nutrient normally present in foods, low levels of selenium are normally found in body tissues and urine. Tests for selenium are most useful for people who have recently been exposed to high levels. Samples of blood, urine, or nails can be properly collected in a physician's office and sent to a laboratory that has the special equipment needed to measure selenium. Urine can be used to determine short-term exposure. Because red blood cells last about 120 days before they are replaced by newly made red blood cells, the presence of selenium in red blood cells can show whether a person was exposed to selenium during the 120 days before testing, but not if exposed more than 120 days before testing. Toenail clippings can be used to determine longer term exposure.

Many methods are available to measure selenium levels in human tissue and the environment. However, none of the methods that are routinely available can measure or detect each selenium compound in one test, and better tests that measure lower levels of different selenium compounds are needed. Also, these tests cannot determine the exact levels of selenium you may have been exposed to or predict whether health effects will occur.

In the United States, normal selenium amounts have been reported in blood as 80–300 ppb and in urine as 7–200 ppb. The results of other studies of average populations and those that have been exposed to higher levels may serve as a guideline. In China, the average selenium amounts in the general population were 95 ppb in whole blood and 26 ppb in urine. In 350 healthy Italian subjects living in the same region of northern Italy, the mean selenium value was 107.5 ppb in blood and 22.1 ppb in urine. Among ranchers who live in western South Dakota and eastern

Wyoming where the soil is naturally high in selenium, the amount of selenium in blood was 317 ppb, and selenium in urine ranged from 10 to 462 ppb. The latter study is considered by some to suggest that, when people are exposed over a long period to higher-than-normal amounts of selenium, their bodies adjust to the higher amounts. Unfortunately, the differences between studies on populations in such areas make it difficult to compare the results.

People in China who had eaten food that was very high in selenium over a long time developed signs of selenosis. These people had an average blood level of 3,200 ppb, about 7 times the highest amount found in the study of the western U.S. population living in an area with high selenium levels in the soil. The amount of selenium in blood in the U.S. study was also compared with an average amount of 206 ppb found in subjects from 19 other U.S. cities. The researchers reported that in the ranchers mentioned above, there was no association between how often physical symptoms occurred and the amount of selenium in blood (up to 206 ppm). However, very high amounts of selenium in blood are clearly related to selenosis.

Chapter 3 contains more information on studies that have measured selenium amounts in human tissues.

The length of time that selenium stays in the body after exposure stops depends on the form of selenium to which the person was exposed. Thus, it is difficult to predict how useful a test will be if some time has gone by since exposure stopped. Chapter 7 contains more information on the methods available to measure selenium in human tissues and in the environment.

1.9 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government develops regulations and recommendations to protect public health. Regulations can be enforced by law. Federal agencies that develop regulations for toxic substances include the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration (FDA). Recommendations provide valuable guidelines to protect public health but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH).

Regulations and recommendations can be expressed in not-to-exceed levels in air, water, soil, or food that are usually based on levels that affect animals; then they are adjusted to help protect people. Sometimes these not-to-exceed levels differ among federal organizations because of

different exposure times (an 8-hour workday or a 24-hour day), the use of different animal studies, or other factors.

Recommendations and regulations are also periodically updated as more information becomes available. For the most current information, check with the federal agency or organization that provides it. Some regulations and recommendations for selenium include the following:

The EPA Office of Drinking Water regulates the amount of selenium allowed in drinking water. Public water supplies are not allowed to exceed 50 ppb total selenium.

The FDA regulations allow a level of 50 ppb of selenium in bottled water. OSHA is responsible for setting regulations on selenium levels allowable in the workplace. The exposure limit for selenium compounds in the air for an 8-hour period is 0.2 mg selenium/m^3. Table 8-1 contains other regulations and guidelines for selenium.

1.10 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop E-29
Atlanta, GA 30333

* Information line and technical assistance
Phone: 1-888-42-ATSDR (1-888-422-8737)
Fax: 1-404-498-0057

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

* To order toxicological profiles, contact

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: 1-800-553-6847 or 1-703-605-6000